



Hydrodynamic Analysis of Relativistic Heavy-Ion Collisions at the RHIC Energy

~A novel and dynamical approach to jet quenching*~

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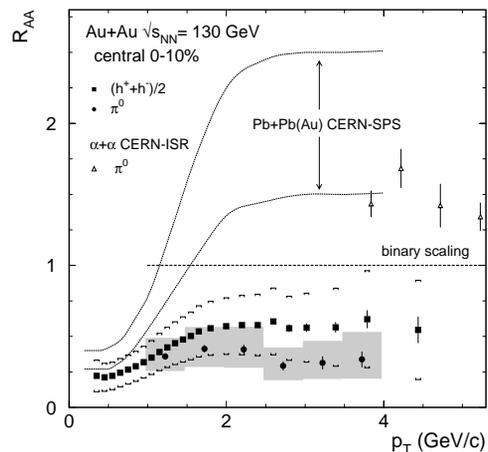
Outline

- Introduction & Motivation
- Hydro+Jet Model
- Results @130A GeV
- Results @200A GeV
- Summary

*T.Hirano and Y.Nara, hep-ph/0208029
(to appear in PRC).

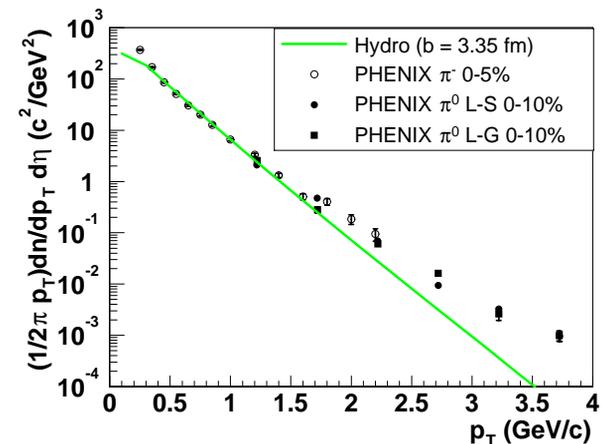
Introduction & Motivation

Observation of jet quenching at RHIC



PHENIX, PRL88(2002)022301.

A result from hydrodynamics with early chemical freeze-out*



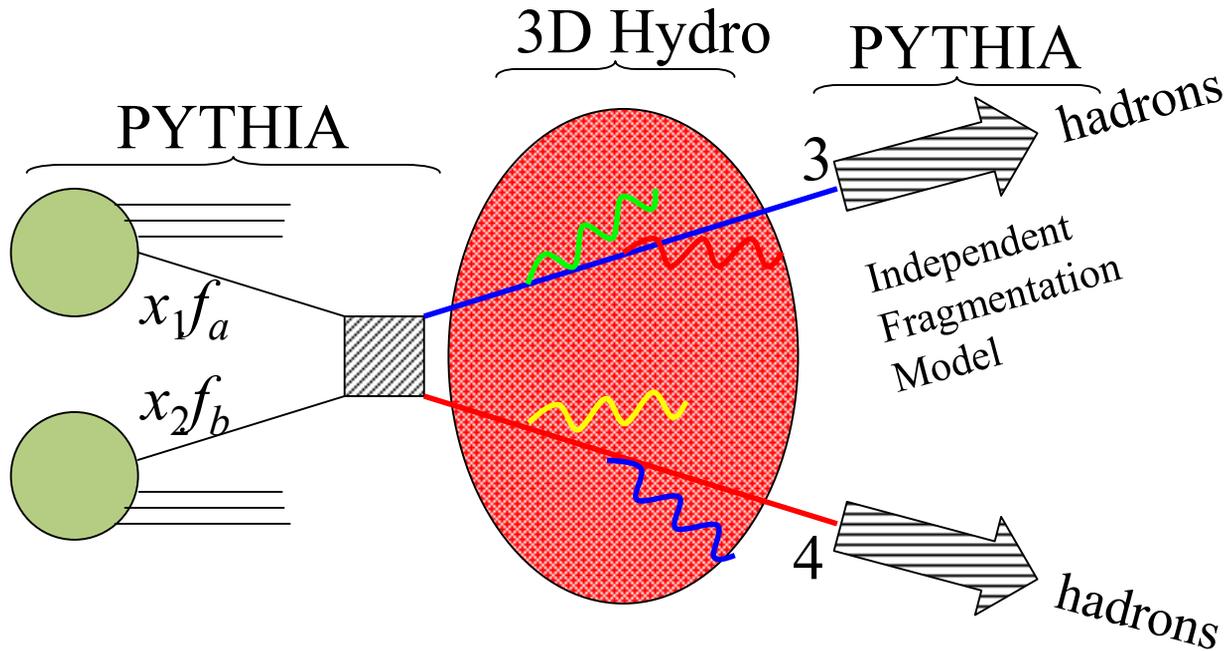
*T.Hirano and K.Tsuda, nucl-th/0205043
(to appear in PRC).

Hydro+Jet model:

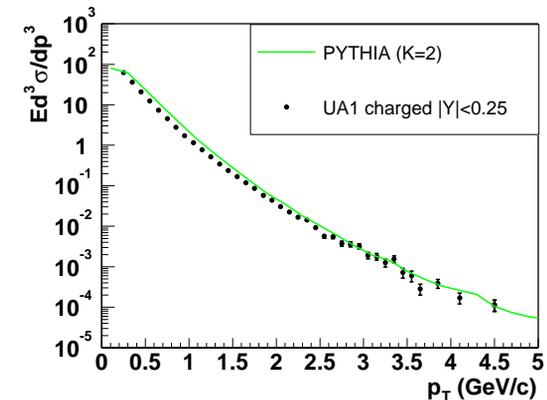
Soft : **Full 3D** hydrodynamics (with early chemical f.o.)

Hard: pQCD with phenomenological parton energy loss

Hydro+Jet Model



UA1, p+pbar 200GeV



•Parton energy loss (toy model):

$$\frac{dE}{dx} = \frac{\varepsilon}{\lambda} = \varepsilon \sigma \rho(\tau, r)$$

From hydro simulation

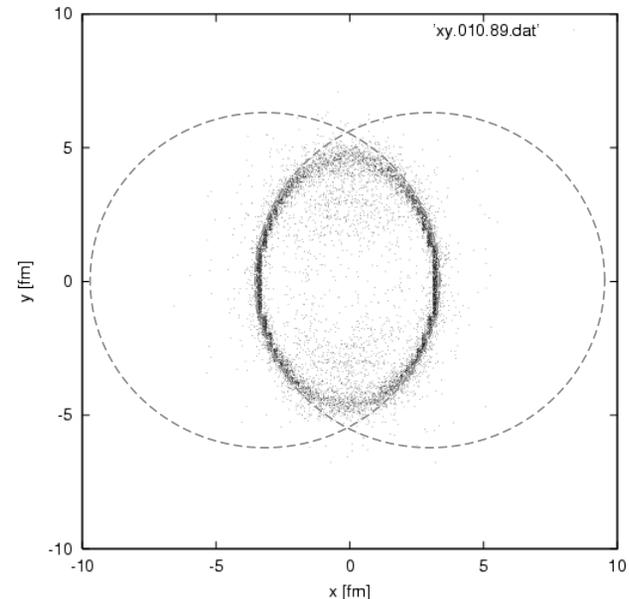
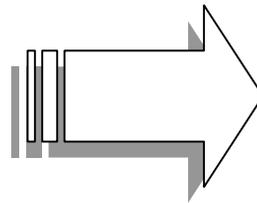
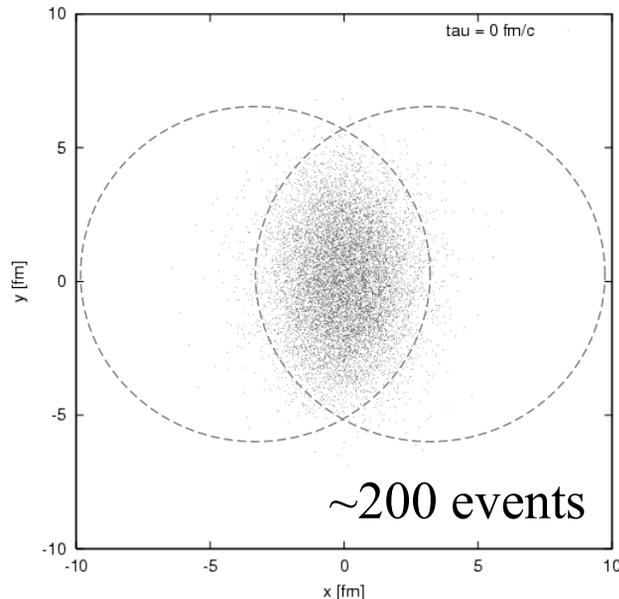
λ : mean free path

ρ : thermalized parton density

σ : parton-parton cross section

ε : energy loss per scattering

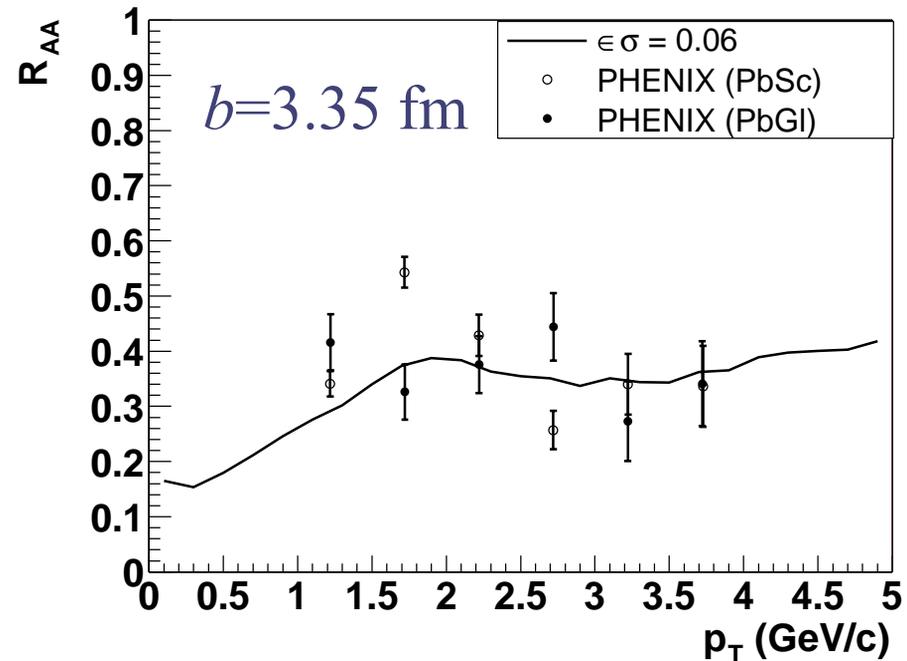
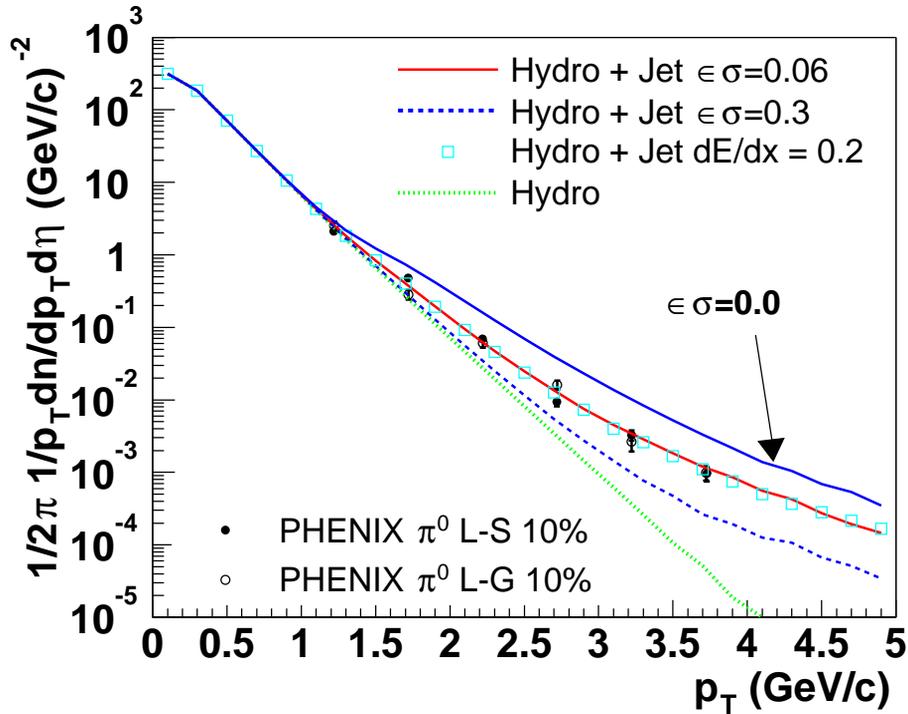
Parton Evolution in the Transverse Plane



- Initial configuration of partons
→ Prop. to # of **binary collisions**
- Momentum distribution
(on-shell partons with $p_t > 2$ GeV/c)
← PYTHIA 6.2

- Assuming partons move along straight paths (eikonal app.)
- Stop just after coming out from the mixed phase (for illustration purpose)

π^0 Spectra in $s_{NN}^{1/2}=130$ GeV Central Collisions

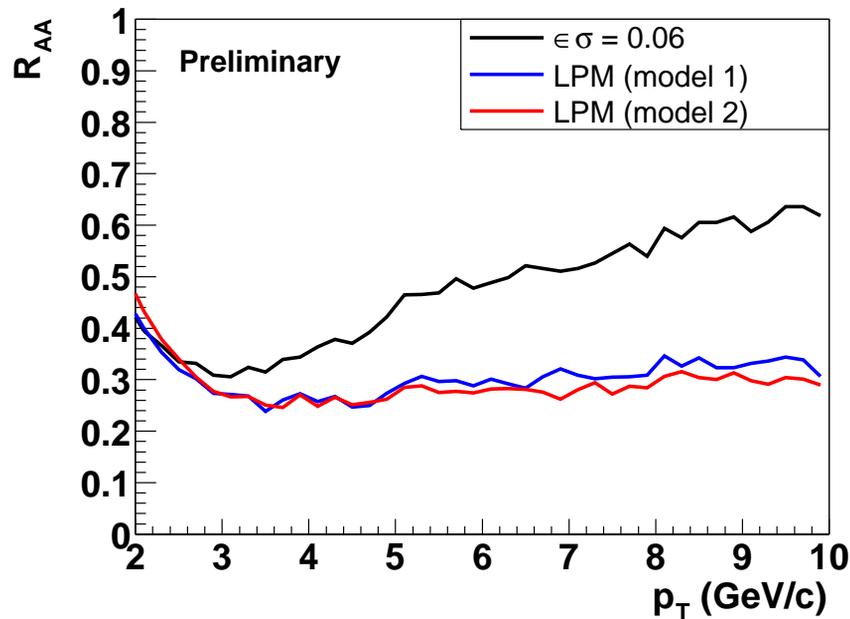


$$\frac{dE}{dx} = 0.06 \rho(\tau, r) [\text{GeV/fm}]$$

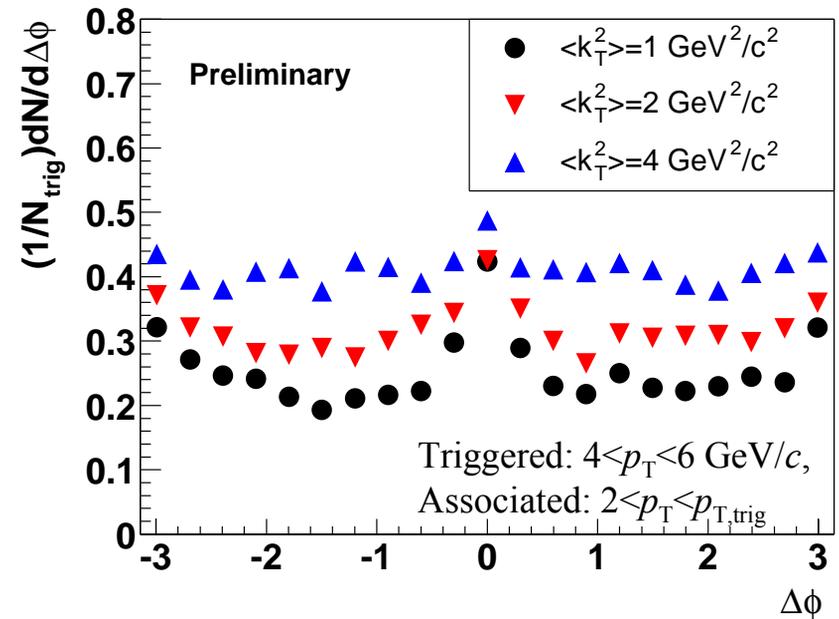
$$\Leftrightarrow 0.2 [\text{GeV/fm}]$$

$$R_{AA}(p_T) = \frac{d^2 N^{A+A} / dp_T d\eta}{\langle N_{\text{binary}} \rangle d^2 N^{N+N} / dp_T d\eta}$$

Results in $s_{NN}^{1/2}=200$ GeV Central Collisions



- Suppression factor R_{AA}
Incoherent model: increase
Coherent model: almost flat



- Back-to-back correlation of jets
Energy loss + intrinsic k_T
Intrinsic k_T is **not** the origin
of disappearance of
back-to-back correlation!

Summary

- We construct the **Hydro+Jet** model as a **dynamical approach** to the physics of jet quenching.
 - **Au+Au 130A GeV**
 - The onset of hard contribution
→ $p_T \sim 2 \text{ GeV}/c$ for pions
 - $\langle dE/dx \rangle = 0.2 \text{ GeV}/\text{fm}$ (\iff HIJING: $0.25 \text{ GeV}/\text{fm}$)
($dE/dx \sim 0.85 \text{ GeV}/\text{fm}$ @ $\tau_0 = 0.6 \text{ fm}/c$ for incoherent model)
 - **Au+Au 200A GeV**
 - $R_{AA}(p_T)$ is sensitive to the model dE/dx .
 - Disappearance of b-to-b correlations does not directly result from intrinsic k_T .

Models for Parton Energy Loss

•Incoherent model

$$\frac{dE}{dx} = \varepsilon \sigma \rho(\tau, \mathbf{x}(\tau))$$

•Coherent (LPM) model

“Transport” coefficient

$$\hat{q}L_{\text{eff}}^2 = \int_{\tau_0}^{\tau_f} d\tau \rho(\tau, \mathbf{x}(\tau)) (\tau - \tau_0) \log \left(1 + \frac{2E}{L\mu^2(\tau)} \right)$$

1. Model motivated by GLV 1st order or BDMPS for $E > E_{\text{cr}}$

$$\Delta E = a \hat{q}L_{\text{eff}}^2$$

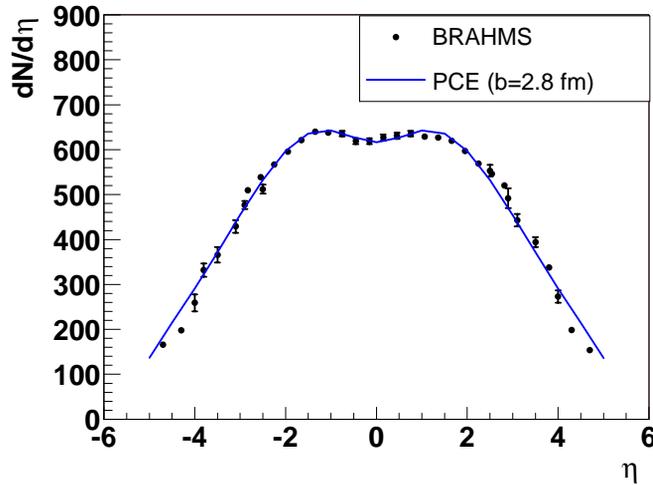
2. Model motivated by BDMPS for $E < E_{\text{cr}}$

$$\Delta E = b \sqrt{E \hat{q}} L_{\text{eff}}$$

1. M.Gyulassy *et al.*, Nucl.Phys.**B571**(2000)197.

2. R.Baier *et al.*, Nucl.Phys.**B483**(1997)291.

p_T Spectra in Au+Au 200A GeV Collisions



Parton energy loss

Incoherent:

$$\frac{dE}{dx} = \varepsilon \sigma \rho = 0.06 \rho$$

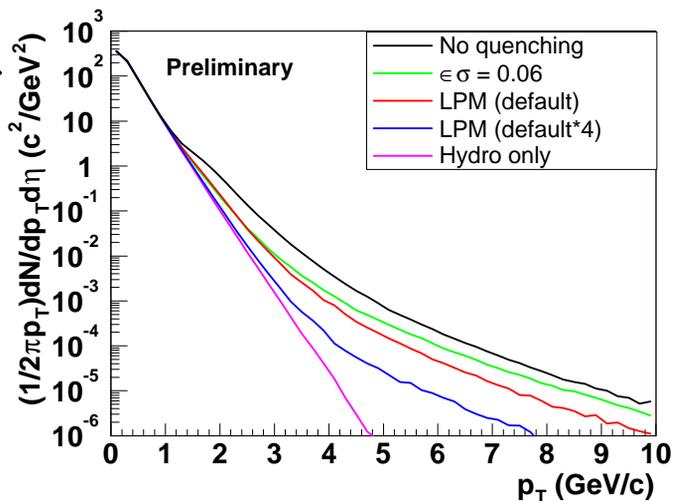
LPM (-motivated E -dependence):

$$\frac{dE}{dx} = a \sqrt{bE} \log \left(1 + \frac{2E}{m^2 L} \right) \rho$$

$$a=0.08 \text{ fm}^{-1}, b=0.35 \text{ GeV}$$

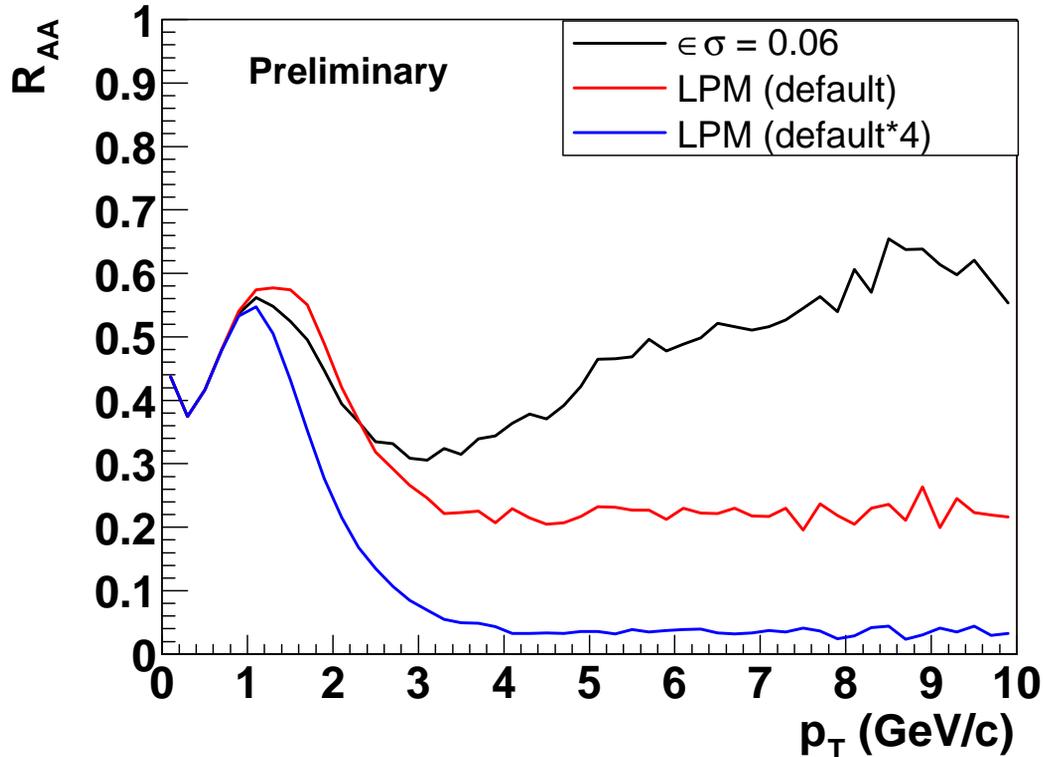
$$L \sim 7 \text{ fm}$$

m : screening mass from
the Polyakov loop model*



* A.Dumitru and R.D.Pisarski, Phys.Lett.B525(2002)95.

Ratio to Binary Collisions



Au+Au 200A GeV

Impact parameter $b=2.0\text{fm}$

Parton energy loss:

$$\frac{dE}{dx} = a\sqrt{bE} \log\left(1 + \frac{2E}{m^2 L}\right) \rho$$

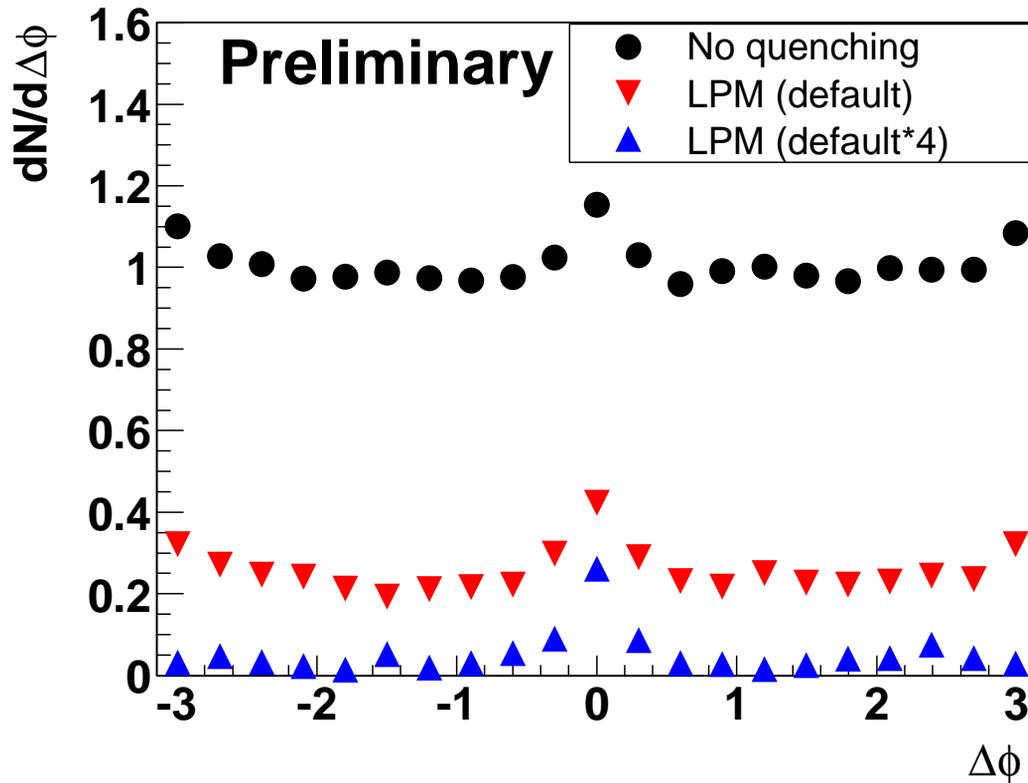
$$a=0.08\text{fm}^{-1}, b=0.35\text{GeV}$$

$$L\sim 7\text{fm}$$

m : screening mass from
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$$R_{AA}(p_T) = \frac{d^2 N^{A+A} / dp_T d\eta}{\langle N_{\text{binary}} \rangle d^2 N^{N+N} / dp_T d\eta}$$

(Disappearance of) Back-to-Back Correlation



Au+Au 200A GeV

Impact parameter $b=2.0\text{fm}$

Parton energy loss:

$$\frac{dE}{dx} = a\sqrt{bE} \log\left(1 + \frac{2E}{m^2 L}\right) \rho$$

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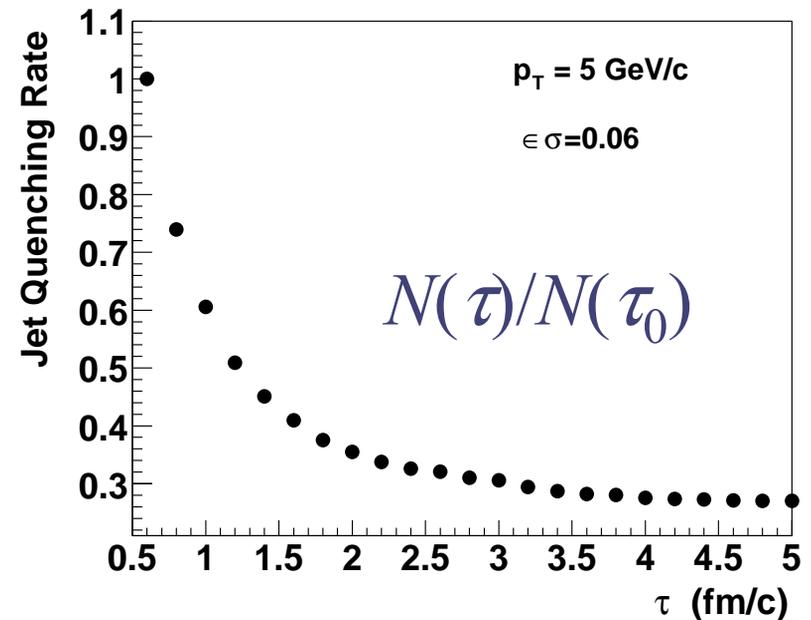
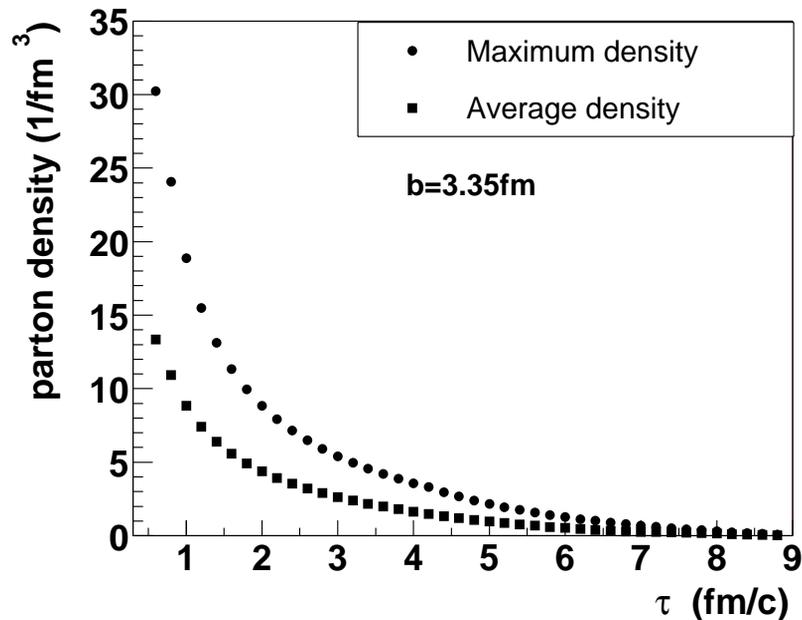
$$L\sim 7\text{fm}$$

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Triggered: $4 < p_T < 6 \text{ GeV}/c$, associated: $2 < p_T < p_{T,\text{trig}}$

When Jet Quenching Happens?

$\rho(\tau)$ at midrapidity from hydro



$dE/dx \sim 0.85\text{ GeV}/\text{fm}$ at τ_0
 Strong longitudinal flow
 dilutes the system. $\rho(\tau) \sim 1/\tau$

Suppression happens in very early stage!

← Need to check LPM case
 $\Delta E \propto \int d\tau (\tau - \tau_0) \rho(\tau)$